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Fatigue-Based Classification of Loading Processes

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Abstract

The given research is associated with the establishing the parameters of vibration processes influencing transport systems and transported objects and causing their fatigue damage. These parameters are applied during the fatigue tests of designed transport products and transported goods, as well as during fatigue testing of structural materials for the construction of fatigue curves and the calculations of products and their components for the resource.

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Keywords: random processes; fatigue; resource; expectation; mean square deviation; process structure criterion.

1. Introduction

Full-scale tests of transport equipment and transported objects show that acting load is a random process which in certain periods of time (at constant speeds) may be regarded as stationary and ergodic [1-4]. At the stage of the development of new designs experimental data on the loads is often used obtained on similar products - prototypes, which, however, cannot be fully valid for new designs. They should be assessed by calculation of load based on dynamic model designed for specific operating conditions which allows you to obtain necessary statistical characteristics of stress-strain state for the calculation of the resource.

To be able to use the ultimate state, namely the fatigue curve which is obtained when the harmonic loading [5-10], holding schematic random processes is required. It is known [1, 11, 12] that the use of schematic methods in conjunction with standard curves of fatigue give significant errors in resource estimations the value of which cannot be predicted. It is obvious that the most rational decision in the calculation of resource and the fatigue strength margin under random loading is to get the fatigue curves of the material and components in terms of the same

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random loading which is experienced by the construction in operation. A large number of structural loading conditions lead to an extremely large scale of experimental studies that are practically unrealizable neither in terms of time nor for economic reasons.

Nomenclature

σ	the stress value
σ_m	the mathematical expectation value of stress
$\sigma_{\min}$	the minimum level of stresses which affect to durability
$\sigma_{\max}$	the maximum level of stresses
S	the mean square deviation of stress value
S_{sin}	the mean square deviation of stress value of harmonic process
S_m	the mean square deviation of positive maxima of the process
S_{ms}	the mean square deviation of damaging maxima
n_0	the average number of random intersections by a random centered process of zero level (number of zeros)
n_0*	the number of zeros per unit time
n_s	the average number of damaging maxima
n_m	the average number of positive maxima of the process
n_{max}	the average number of maxima of the processes
N_0	the parameter of durability
G	the criterion of the process structure
G_{sin}	the criterion of the harmonic process structure
T	the operation period
P	the probability
i	the coefficient of irregularity
$f_m(\sigma)$	the maxima probability density function
ω_e	the effective frequency of the process
$R_\sigma(0)$	the correlation function of stress at $\tau = 0$
$R_{\dot\sigma}(0)$	the first derivative of the correlation function of stress at $\tau = 0$
$S_\sigma(\omega)$	the spectral density of stress

2. The characteristics of random process

Let us consider a number of characteristics that define the parameters of a random loading process in a construction used to evaluate a resource [1, 8, 13-19]. Mathematical expectation (mean value) σ_m is used as the abovementioned characteristics which characterizes the static moving of the process of stress change σ, mean square deviation (MSD) of stresses S which characterizes load intensity.

These numerical values define one-dimensional function of normal law of distribution of stress ordinates but not uniquely characterize a random process, as for fixed values of σ_m and S there is a large number of different implementations with different density of the probability distribution of the maxima of this process.

The experimental data on fatigue of various alloys indicates that the durability for these processes with equal values of σ_m and S are different and considered options for the characterization of damage by random processes are not enough. Let us consider the maxima of random processes. Depending on the internal structure of random processes maxima probability density function can vary at fixed σ_m and S. These functions can be provided by Rice dependency

$$f_m(\sigma) = \frac{1}{S}\left\{\sqrt{\frac{1-i^2}{2\pi}}\exp\left[-\frac{\sigma^2}{2S^2\left(1-i^2\right)}\right] + i\frac{\sigma}{S}\exp\left(-\frac{\sigma^2}{2S^2}\right)F\left(\frac{i\sigma}{S\sqrt{1-i^2}}\right)\right\} \tag{1}$$